

100-N Area Strontium-90 Treatability Demonstration Project: WBS-01: Phytoremediation Along the 100-N Columbia River Riparian Zone - Field Treatability Study

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PNNL-SA-61839

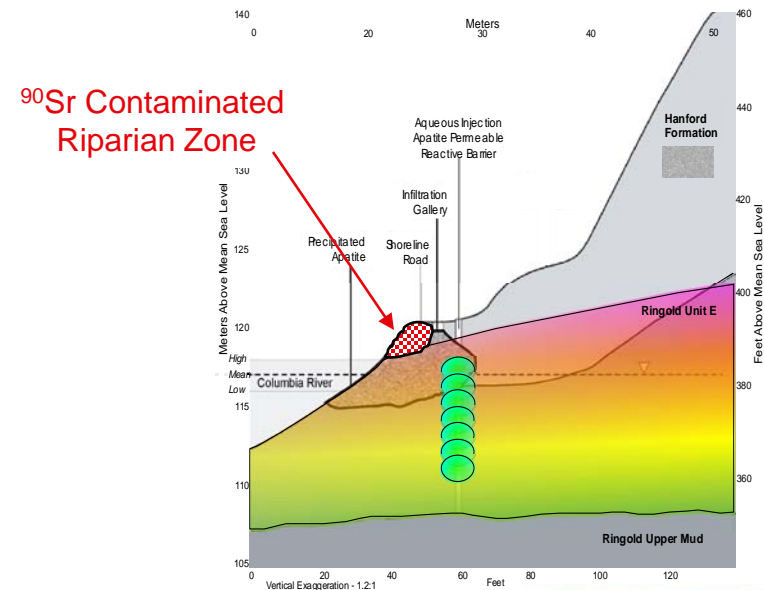
Pacific Northwest National Laboratory

Polyphosphate Injection -Apatite Treatment Plan

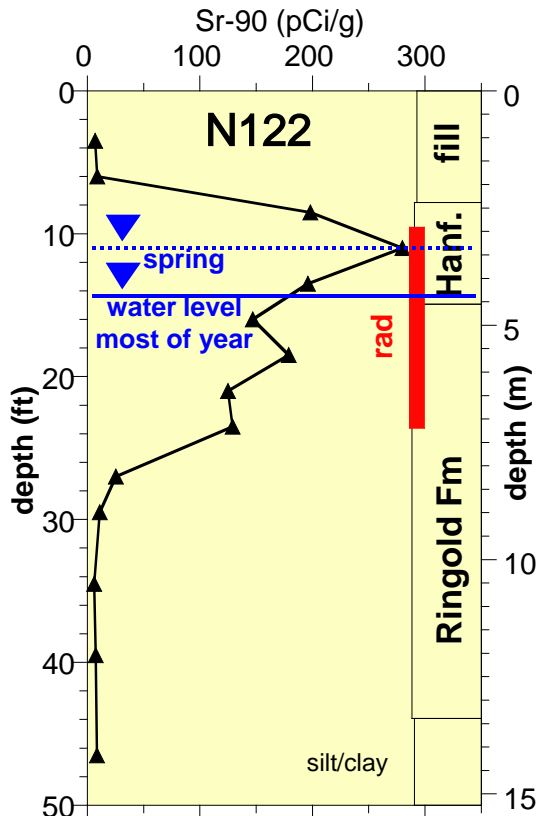
- Primary Recommendation of ITRD Committee.
- This approach does not address contaminated sediment in vadose and riparian zones of bank.
- ITRD suggested Phytoremediation as a polishing step in the riparian zone.



100-N



Phytoremediation



Strontium-90 distribution in soil profile at 100-N shoreline

- **Phytoremediation** - a managed, defined, remediation technique in which plants are employed to extract soil contaminants thus reducing the amounts of biologically available soil contaminants to regulatory acceptable levels with minimal soil disturbance.
- **Rhizofiltration** - A managed, defined remediation technique in which plants extract contaminants from water flowing through the root mass.
- **Proposed plant - Coyote Willow (*Salix exigua*)**
 - Native Species
 - Phreatophyte – roots invade water table
 - Growth Characteristics
 - Dioecious, rapidly grown from cuttings (large biomass production)
 - Shrub-like growth habit, Capable of rapid regrowth after harvesting
 - Root Characteristics
 - Fibrous root structure
 - Root system tolerant of poor drainage and prolonged flooding
 - Sr extraction from vadose zone, groundwater filtration



Phytoremediation Questions

- Efficiency

- Are the plants capable of accumulating Sr?
- Is the amount of accumulation sufficient to make the technique viable?
- Will the plants produce sufficient biomass?
How can this be optimized? (management practices)

- Safety

- How can we prevent off-site transfer of detritus (leaves, stems)?
- How can we prevent possible herbivore intrusion?
 - Large and small animals
 - Insects
- What is the clean-up strategy?

Can Plants Accumulate Sr?

- Sr is a Ca nutrient analog - plants do not readily differentiate between the two ions.
 - Mass flow is mainly responsible for Ca and Sr transport to the plant root.
 - Sr uptake by plants will be proportional to the [Ca/Sr] in the soil solution (porewater) and ^{90}Sr uptake will be proportional to the [$^{90}\text{Sr}/\text{Sr}$].

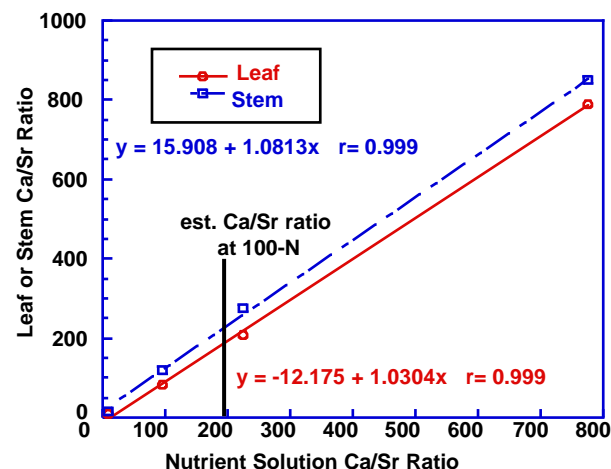
- Laboratory Studies Supported by Fluor Hanford in FY-04

- Hydroponic Studies**

- No significant differentiation of Ca and Sr uptake by willows
- No Sr – ^{90}Sr differentiation

- 100-N Sediment Studies**

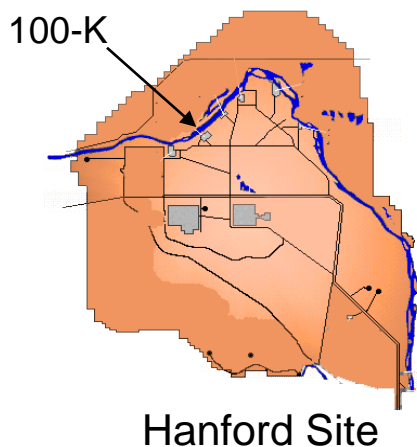
- Plant $\text{CR}^* = 66$
 - $\text{CR} = \text{Concentration Ratio or } (\text{pCi/g dry wt. plant tissue}) / (\text{pCi/mL soil porewater})$
- Plant Extraction - 0.065 nCi/g



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DOE (FY-07) and Fluor (FY-08) Field Treatability Study



- Management practices – Optimization of biomass production and ^{90}Sr removal (6 mo. FY07)
 - Fertility practices using Hanford Formation Sediment– Greenhouse (completed)
- Biomass production in natural environment (FY07 – FY09)
 - Demonstration plot – 100-K riparian zone
- Control of off-site transport (FY07 – FY09)
 - Different harvesting strategies (biannual), Barriers – 100-K riparian zone

100-K West Plot Set-Up 3/05/07

- Stakes obtained from Wildlands, Inc., of Richland, WA
 - Coyote Willows (*Salix exigua*) from Yakima River near Benton City, WA (20 miles E of 100-K)
- Proximal end (closest to trunk) placed in water with Rootone® (Garden Tech Inc., Lexington, Kentucky) and kept in distilled water for 14 days until roots and shoots have been initiated from the stem.



Root Initials on Stake



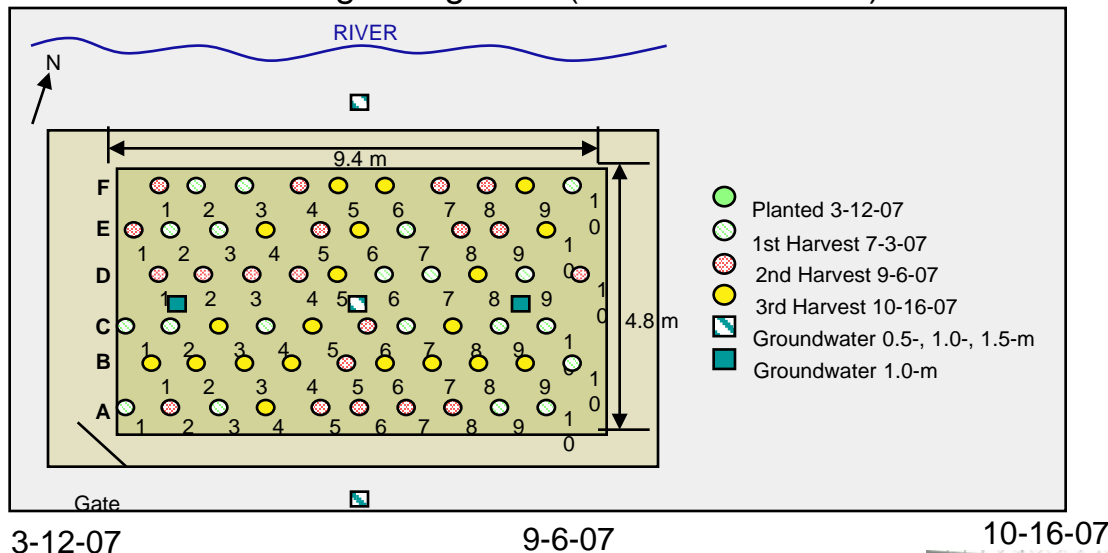
Placing Plants



Completed Planting

Field Treatability Plot

- Diagram of plot with dates and positions of plants harvested in '07.
- Harvesting consisted of removing new growth (stems and leaves) down to the second nodes.



Plant Dry Matter Accumulation

- Plant dry wt. (g) from all three harvests in first season.

Harvest Date	Days of Growth Prior to Harvest	Total Tissue (Stems and Leaves) Harvested Dry Wt.	Total Leaf Tissue Harvested Dry Wt.	Average New Tissue per Plant	Estimated Kg Dry Wt/Hectare from Individual Plant Averages ¹
		(g)	(g)	(g) Avg.±S.D.	
7/06/07	117	263.4	161.7	13.2±5	132
9/14/07	187	320.5	214.3	16.0±8.6	160
10/17/07	220	369.9	255.3	18.5±9.7	185
10/17/07 Re-growth from 1 st Harvest	103 ²		102.9 ³	5.1±3.6 ³	

¹. The plot size = 0.00456 Hectares, and 1 Hectare = 10,000 m², also at 3 ft (~ 1 m) centers we would have a matrix of 100 x 100 trees or 10,000 trees. This means individual plant weight times 1x10⁴ would approximate anticipated yield.

². Days between first harvest and third.

³. Weight of leaf tissue only. This was used as a standard comparison to the other harvests as leaf initiation was more prevalent than stem growth following harvest.

- Dry weight yield obtained in 2007 is about 2% of the proposed 10 Kg/Ha estimated as a target harvest weight for mature trees. This initial season's growth was from cuttings of very young saplings.

- The first year's growth is expected however when compared to the data of R.F. Kopp et al., Biomass and Bioenergy 20:1-7. 2001. For cloned willow trees in New York State

Plant Tissue Analysis

- Tissue analysis shows Ca/Sr ratio is maintained over growing season.
- Plant concentrations of both Ca and Sr increase over time.

Tissue	Harvest Š 1 Jul 2007 Average Ca Concentrations	Harvest Š 1 Jul 2007 Average Sr Concentrations	Harvest Š 1 Jul 2007 Average Ratio of Ca/Sr Concentrations	Harvest Š 2 Sep 2007 Average Ca Concentrations	Harvest Š 2 Sep 2007 Average Sr Concentrations	Harvest Š 2 Sep 2007 Average Ratio of Ca/Sr Concentrations
	(mg/Kg dry wt.) \pm S.D.	(mg/Kg dry wt.) \pm S.D.	(mg/Kg dry wt.) \pm S.D.	(mg/Kg dry wt.) \pm S.D.	(mg/Kg dry wt.) \pm S.D.	(mg/Kg dry wt.) \pm S.D.
Leaves	7935 \pm 3167	34 \pm 14	235 \pm 31	17910 \pm 2902	92 \pm 21	199 \pm 33
Stem	5400 \pm 1033	30 \pm 5	180 \pm 17	9565 \pm 1686	53 \pm 12	182 \pm 21
Total	6668 \pm 2656	32 \pm 10	208 \pm 37	13737 \pm 4832	73 \pm 26	191 \pm 29

Groundwater Analysis

- Groundwater [Ca/Sr] Ratio ($\mu\text{g/L}$)

Water Sample Depth	4/28/07 [Ca/Sr] Ratio	6/20/07 [Ca/Sr] Ratio
m	Avg. $\mu\text{g/L} \pm \text{SD}$	Avg. $\mu\text{g/L} \pm \text{SD}$
1.0	223 \pm 20	278 \pm 87
1.5	305 \pm 40	318 \pm 38
2.0	317 \pm 29	294 \pm 11

Lessons Learned in FY-07

- The Columbia River is a dominant force.
 - Access restrictions caused inevitable delays and variances in schedule and costs.
- The willow is hardy and will grow under these conditions.
 - Dry matter accumulation for the first year is acceptable as the plants are just establishing themselves.
- Plant uptake of Sr is in direct relation to the $[Ca/Sr]$ ratio of the soil water. Total plant concentrations of Ca and Sr increase with growth.
- Fencing will exclude large and small animal herbivores.

Field Effort - 2008

- Initial inspection of plants revealed 5 of the 50 showed no new growth as of February 22.
- At this time weeds around the plant were cut and new fertilizer spikes were placed.
- Within 20 days of this the River had flooded the site.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

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Plot Images in 2008

- Plants have recovered following flooding and are showing vigorous growth.
- Management practices of fertilizing and weeding are underway.



June 18, 2008



June 24, 2008



July 21, 2008

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Earned Value Report

Phytoremediation Field Treatability Study	FY-08
BCWS	\$46,533
BCWP	\$38,340
ACWP	\$39,699
SV	-\$8,193
CV	-\$1,320

- Values reflect work delays and accompanying lower expenditures caused by River inundation of plot.
- Schedule is being re-baselined to reflect field conditions